



Fermi National Accelerator Laboratory

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CDF

$J/\psi, \psi' \rightarrow \mu^+ \mu^-$ and $B \rightarrow J/\psi, \psi'$ Cross Sections

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ABSTRACT

This paper presents a measurement of $J/\psi, \psi'$ differential cross sections in $p\bar{p}$ collisions at $\sqrt{s} = 1.8$ TeV. The cross sections are measured above 4 GeV/c in the central region ($|\eta| < 0.6$) using the dimuon decay channel. The fraction of events from B decays is measured, and used to calculate b quark cross sections and direct $J/\psi, \psi'$ cross sections. The direct cross sections for the ψ' are found to be more than an order of magnitude above theoretical expectations.

1. Introduction

Charmonium production is currently the best way to study b quark production at CDF at the lowest transverse momentum of the b . While the signal-to-noise for the J/ψ is excellent, conclusions regarding b production are dependent on the fraction of the sample due to b decays. One way of determining this fraction is to use the decay distance of the J/ψ state. In contrast, the fraction of ψ' 's from b decays was thought to be close to one.¹ In using ψ' events to study b quarks, one should not have to worry about the fraction due to b decays. However, a very large zero-lifetime component for the observed ψ' signal is seen. Therefore, one still must make use of the lifetime information.

The CDF detector has been described in detail elsewhere.² We mention here briefly the components relevant to this analysis. A solenoidal magnet generating a 1.4 T magnetic field surrounds the two tracking chambers used. The Central Tracking Chamber (CTC) is a cylindrical drift chamber surrounding the beam line. The Silicon Vertex Detector (SVX) is a silicon microvertex detector that provides an impact parameter resolution of $(13+40/P_T)\mu\text{m}$. Because the SVX is shorter than the interaction region, only about 60% of the CTC tracks pass through the SVX. Outside the CTC are electromagnetic and hadronic calorimeters, which provide five absorption lengths of material before the Central Muon Chambers (CMU).

2. Event Selection

Events are selected from a dimuon trigger. Both muons are required to have $P_T^\mu > 2.0$ GeV/c and one muon must have $P_T^\mu > 2.8$ GeV/c. The dimuon is required to have $|\eta^{\mu\mu}| < 0.6$ and $P_T^{\mu\mu} > 4$ GeV/c. The tracks are constrained to improve the mass resolution, and the resulting invariant mass is used to define signal regions of $3.0441 < m_{\mu\mu} < 3.1443$ GeV/c² for the J/ψ and $3.636 < m_{\mu\mu} < 3.736$ GeV/c² for the ψ' . Sideband regions from $2.9606 < m_{\mu\mu} < 3.0274$ GeV/c² or $3.1610 < m_{\mu\mu} < 3.2278$ GeV/c² for the J/ψ and of $3.52 < m_{\mu\mu} < 3.62$ GeV/c² or $3.75 < m_{\mu\mu} < 3.85$ GeV/c² for the ψ' are used.

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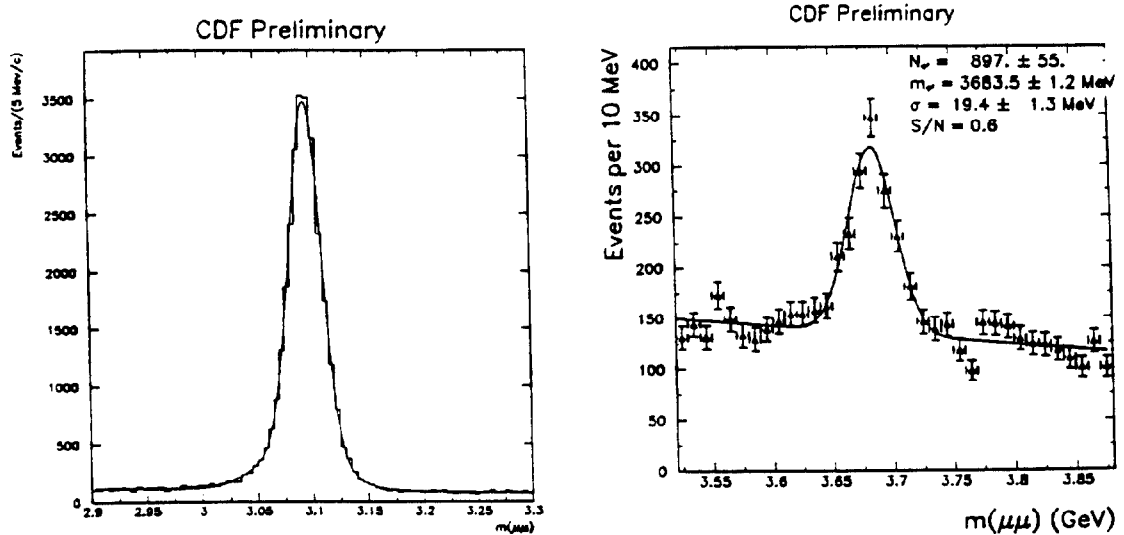


Fig. 1. Mass distribution (J/ψ , ψ')

3. b Fraction

For events where both muons have well-measured SVX tracks, we vertex constrain the tracks to measure the decay length. This is converted into the proper lifetime of the parent using the $J/\psi, \psi'$ transverse momentum and a Monte Carlo correction factor. The background shape is measured from the sidebands. The signal region is fit to a resolution function, an exponential convoluted with the resolution function, and the background shape. We fix the b lifetime to $438 \mu\text{m}$, as found by the CDF inclusive b lifetime measurement.³

Separate binned fits are done on the J/ψ signal and sideband regions. A log-likelihood fit is performed on the ψ' data. The background fraction is varied within Poisson statistics, but the resolution function is limited to a Gaussian, as measured errors are used. Varying the fitting methods changes the b fraction by 7%, which we assign as the systematic uncertainty.

3.1. P_T dependence

It is expected that the b fraction in the $J/\psi, \psi'$ samples rises with P_T . To measure this, we divide the ψ' sample into three P_T bins from 4 – 6 GeV, 6 – 9 GeV, and 9 – 20 GeV. We repeat the above fitting procedure in each of the P_T regions. In the J/ψ sample, the spectrum of events with $c\tau > 250 \mu\text{m}$ is found. This is divided by the J/ψ spectrum, normalized so that the ratio of the two areas is the inclusive b fraction.

4. Cross Section

4.1. $J/\psi, \psi'$ Cross Section

After correcting the measured P_T distributions for acceptance and efficiencies, we find

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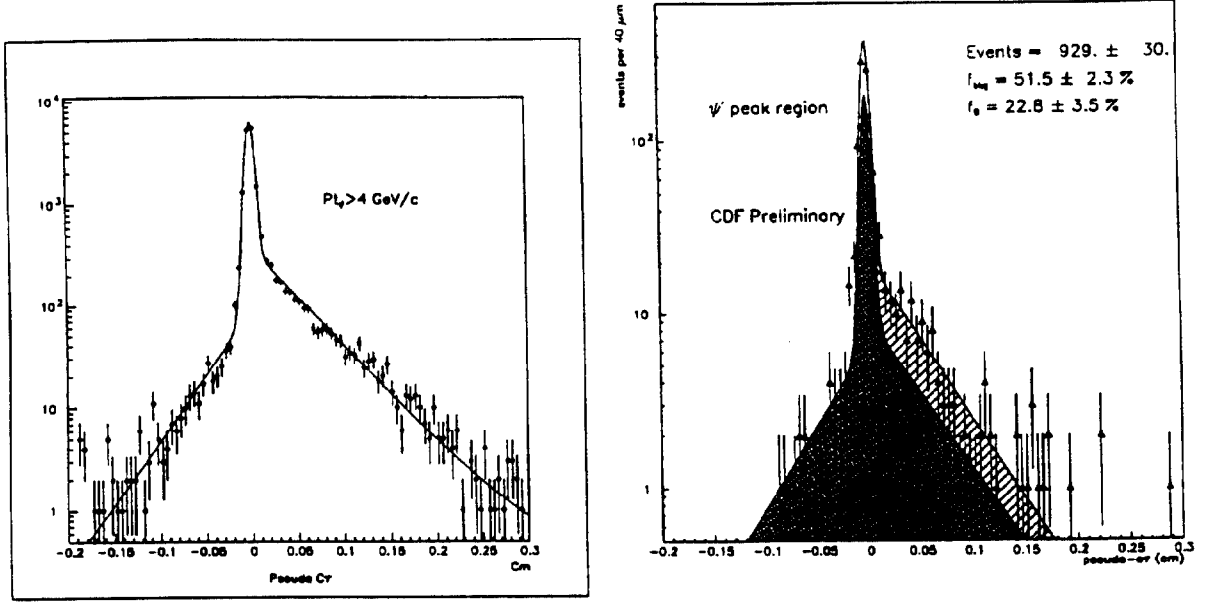


Fig. 2. J/ψ and ψ' Lifetime Distributions. In the ψ' plot, the dark region is the background shape. The slashed region is the B component plus the background shape.

$\sigma(J/\psi) \cdot Br(J/\psi \rightarrow \mu^+ \mu^-) = 29.10 \pm 0.19(stat) \pm_{2.84}^{3.05}(syst)$ nb and $\sigma(\psi') \cdot Br(\psi' \rightarrow \mu^+ \mu^-) = 0.721 \pm 0.058(stat) \pm 0.072(syst)$ nb, where $\sigma(\psi) = \sigma(p\bar{p} \rightarrow \psi X, P_T^\psi > 4 \text{ GeV}/c, |\eta| < 0.6)$. The systematic uncertainties are dominated by the trigger efficiency (7-8%), the polarization (5%), and the luminosity (4%). The cross section from b decays is extracted by multiplying the differential b fraction by the cross section. We also obtain a prompt cross section by multiplying the cross section by one minus the b fraction. The prompt theory curves are from reference.⁴

4.2. Inclusive b Cross Section

The cross sections from b decays are combined with b quark acceptances to produce integrated b quark cross sections. The P_T of the b quark is described by P_T^{min} , the P_T such that 90% of the b quarks in our sample have $P_T^b > P_T^{min}$. We use branching ratios of $Br(b \rightarrow J/\psi X) = 1.16 \pm 0.09\%$,⁵ $Br(b \rightarrow \psi' X) = 0.30 \pm 0.06\%$,⁶ $Br(J/\psi \rightarrow \mu\mu) = 6.27 \pm 0.20\%$ ⁷ and $Br(\psi' \rightarrow \mu\mu) = 0.88 \pm 0.13\%$.⁸ Using the J/ψ , we find $\sigma(6.0 \text{ GeV}/c) = 12.16 \pm 2.07 \mu\text{b}$, $\sigma(7.3 \text{ GeV}/c) = 8.24 \pm 1.34 \mu\text{b}$ and $\sigma(8.7 \text{ GeV}/c) = 5.20 \pm 0.83 \mu\text{b}$. The ψ' results are $\sigma(5.9 \text{ GeV}/c) = 6.12 \pm 2.04 \mu\text{b}$ and $\sigma(8.3 \text{ GeV}/c) = 3.85 \pm 1.23 \mu\text{b}$, where $\sigma(P_T^{min}) = \sigma(p\bar{p} \rightarrow bX, |y^b| < 1.0, P_T^b > P_T^{min})$. The errors are statistical and systematic, added in quadrature. The systematic uncertainties are dominated by the $J/\psi, \psi'$ momentum distribution (5%), Peterson ϵ (5%), and the values of μ and Λ in the NDE spectrum (4.6%). A 4% uncertainty is added to the ψ' values because of the large bin size used in calculating the b fraction.

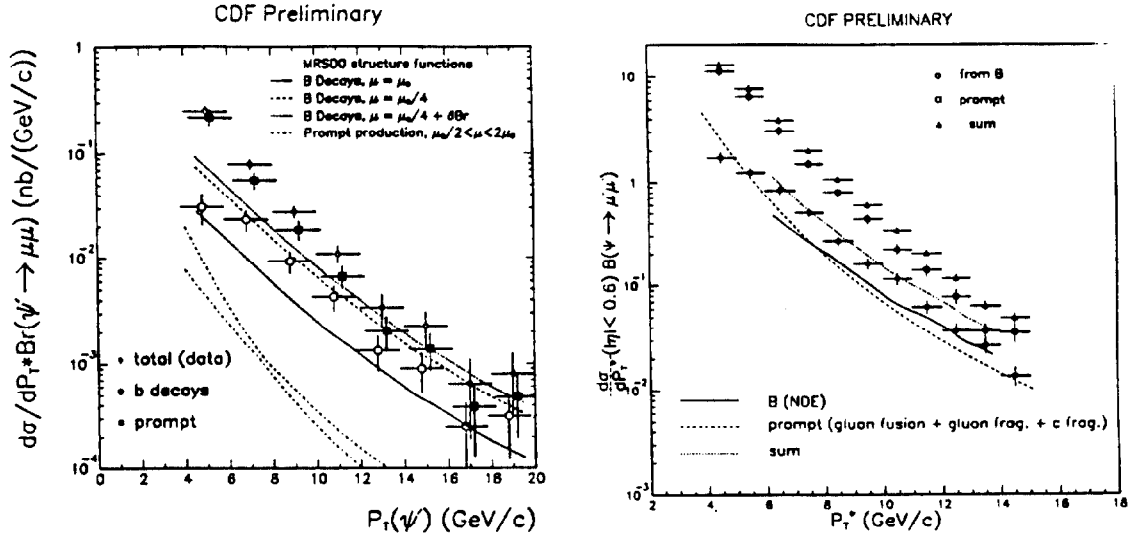


Fig. 3. ψ' and J/ψ Differential Cross Sections. The $b(\text{prompt})$ values have been artificially offset by 200(-200) MeV/c for clarity in the ψ' .

5. Acknowledgements

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